CAMPAIGN OVERVIEW AND INITIAL RESULTS FROM EXPLORATION OF THE MARGIN UNIT IN JEZERO CRATER BY THE PERSEVERANCE ROVER.

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Introduction: Jezero crater was chosen as the landing site for the Mars 2020 mission based on both the presence of a well-preserved delta-like deposit [1,2], potentially indicating a sustained habitable lacustrine environment, and the presence of strong orbital spectral signatures of secondary minerals [3,4]. Strong carbonate signatures are concentrated within a narrow range of elevations along the western margin of the crater (the "margin unit" [5]) that was hypothesized to be a shoreline deposit incorporating authigenic lacustrine carbonate [6,7]. If true, samples acquired from the margin unit would be a compelling target for sample return, as authigenic lacustrine minerals have high biosignature preservation potential. The Perseverance rover has been exploring the margin unit since September 2023, and so far has collected two samples from the margin unit [8]. Here we provide an overview of the Mars 2020 Margin Campaign to date, a summary of key initial results, and preliminary interpretations of depositional settings and paleoenvironments in the Margin.

Margin Campaign Science Goals: Prior to reaching the margin, five goals were identified to guide the Margin Campaign. All of these goals ultimately support the selection of rock cores from the Margin unit for potential return to Earth by Mars Sample Return [8].

Goal 1: Determine emplacement process(es). Several origins have been postulated for the margin unit in addition to the lacustrine hypothesis. The first priority was determining if the margin was related to previously sampled olivine/carbonate-bearing lithologies in Jezero: (1) igneous cumulates on the crater floor and (2) fluviodeltaic deposits on the fan top [6-7,9-10]. The margin has also been linked to olivine/carbonate-bearing rocks outside Jezero, potentially pyroclastic in origin, and altered via surface weathering or groundwater interactions [1,11-13]. An aeolian origin was also considered.

Goal 2: Determine alteration history. Determining the aqueous history of the unit from secondary minerals and diagenetic features will provide important constraints on paleoenvironments. For example, carbonates could be an early/late diagenetic cement, authigenic precipitates, detrital materials, or late digenetic fracture fill.

Goal 3: Determine geologic relationships. To understand how the margin fits into Jezero history, it is necessary to determine the geologic and stratigraphic relationship with crater rim, fan, and crater floor units.

Goal 4: Search for potential biosignatures. To characterize the biosignature preservation potential, it is necessary to identify, characterize, and contextualize any possible organics or biogenic textures from past aqueous environments in the margin.

Goal 5: Constrain paleoenvironment/paleoclimate. If sedimentary, the margin unit may provide constraints on the extent, (relative) timing, duration, and aqueous geochemistry of a paleolake in Jezero, and potentially on paleoclimate at the time of deposition.

Campaign Overview: Perseverance approached the margin from the fan top ~1 km south of Neretva Vallis at Mandu Wall. This area is a topographic low with weaker carbonate and stronger olivine signatures from orbit than the rest of the unit. The first abrasion (Amherst Point) and sample collection (Pelican Point) were conducted at the Hans Amundsen Memorial Workspace. The rover turned north to Turquoise Bay, a topographic high with strong orbital carbonate signatures, for a second abrasion (Bills Bay) and sampling (Lefroy Bay). The rover then conducted a remote sensing survey loop of Gnaraloo Bay, where margin unit outcrops show multiple contacts with overlying fan units. As of this writing, the rover is driving west across the margin unit just south of Neretva Vallis, toward Beehive Geyser, potentially the stratigraphically highest portion of the margin unit, and Bright Angel, where layered materials within Neretva Vallis may underlie the margin unit.

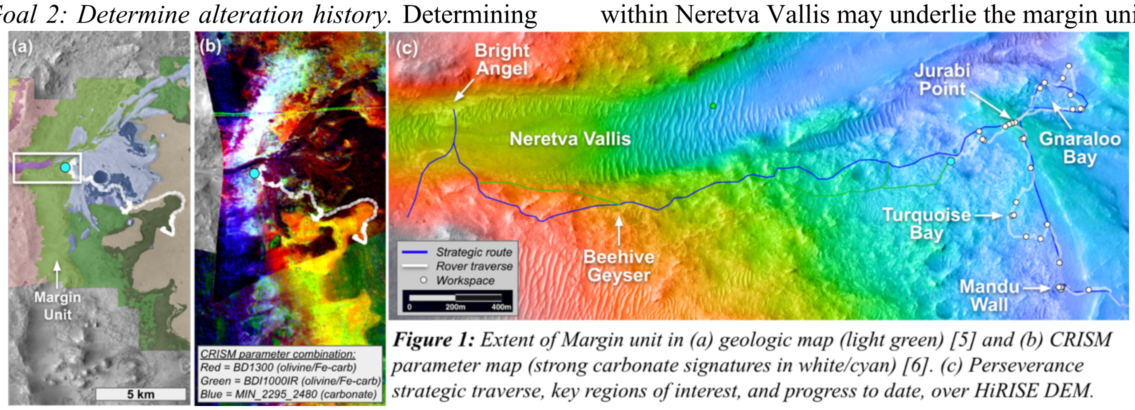

Figure 1: *Extent of Margin unit in (a) geologic map (light green) [5] and (b) CRISM parameter map (strong carbonate signatures in white/cyan) [6]. (c) Perseverance strategic traverse, key regions of interest, and progress to date, over HiRISE DEM.*

Initial Results from the Margin: Data collection and analysis are still ongoing, but observations so far suggest that the margin unit has a distinct origin compared to the western fan in Jezero.

Morphology: Mastcam-Z and SuperCam images (Fig. 2) show that the margin is composed of dark and granular layers of highly variable thickness (<1 to 40 cm) [14,15]. Filled fractures sometimes cut across layers. The unit is typically broken into large polygons, with upturned blocks that appear resistant to erosion, and occasional concentric circular features [14].

Structure: Outcropping layers in the margin are typically horizontal to sub-horizontal, with distinct packages of layers dipping either rimward or basinward, and the layer packages sharply truncate one another [16]. However, the layer dips are shallow, and no steeply dipping cross-beds have been identified. RIMFAX ground penetrating radar has shown an overall structure characterized by up to a few strong radar reflectors that are sub-horizontal to moderately dipping rimward or basinward, with some sets truncating against one another (at 10s to 100s of meters scale and to 10-20 m depth). At smaller scales, some sections host potential trough, hummock, clinoform, and inclined stacks of reflectors.

Spectra: Reflectance spectra from Mastcam-Z and SuperCam of bedrock in the margin unit are dominated by variable olivine, Fe/Mg-carbonate, and hydrated silica signatures [14,15]. Some sandy regolith areas also exhibit strong carbonate features, which may contribute to the orbital carbonate signature [15].

Petrography: Abrasion patches in the margin unit show diverse dark to light-toned sand-sized grains in a heterogeneous matrix [14,17]. PIXL X-ray fluorescence and SHERLOC Raman spectra identify discrete grains of olivine and grains of carbonate, with more rare pyroxene, feldspar, and silica grains, and cements are largely composed of carbonate and hydrated silica with some phyllosilicates [8,18]. Carbonate in the margin is highly diffracting, suggesting a more crystalline structure from slow growth under high water:rock ratios. Mg-sulfates appear to crosscut grains in both abrasion patches and thus are likely late diagenetic in origin, and highly soluble perchlorate and hydrated carbonate may also be late precipitates [8,17,18].

Preliminary Interpretations: The margin unit shows textures and compositions that are distinct from the olivine and minor carbonate-bearing igneous cumulates of the crater floor [9], and is instead consistent with a clastic sediment. Clear indicators of pyroclastics have not been observed (e.g., lapilli, scoria, glass), and abrasion patches show discrete subrounded primary and secondary mineral grains that are more consistent with a sedimentary deposit (a sandstone). However, outcrops so far have also not shown high-angle cross-beds or wind ripple laminae expected for aeolian settings [16].

The margin unit shares some petrological properties with fluviodeltaic sediments on the fan. Some subsurface radar features appear consistent with accretion and erosion (e.g., aggrading beds, bars, scour, channels, overflow) found in braided or successive fluvial systems. But unlike the fan, the distribution of the margin unit as mapped from orbit does not show a clear relationship with the main Jezero inlet, Neretva Vallis. The distribution could be due to a series of alluvial fans along the crater rim (a bajada); however, it is difficult to explain rimward-dipping strata in an alluvial scenario.

It is likely that multiple depositional processes interacted to produce the margin unit, and in situ observations and data analysis is ongoing. However, at this time, the stratigraphy, composition, and distribution observed along the eastern portions of the unit seem to be most consistent with a beach deposit. Lacustrine beach bars can form beds dipping both toward and away from the basin, along with horizontal lake deposits, as observed in the margin [16]. A beach setting is also consistent with carbonate and silica present as reworked rounded grains and cements, as this could represent contemporaneous low energy reworking and cementation of subaqueous or pore-filling precipitates [18], as in Mg-carbonate beach deposits in alkaline lakes [19].

Implications for Sample Return: Abrasion patches in the margin show a unique suite of carbonate and silica precipitates that have the potential to preserve biosignatures and chemical records of lake chemistry [8,17,18, 20]. The margin also may be older than the fan, perhaps pre-dating the western breach of paleolake Jezero [6], and so may preserve an earlier lake phase with different detrital grains. Thus, the two margin unit samples collected so far represent an important contribution to the lithologic diversity, astrobiological potential, and scientific impact of the Mars 2020 sample suite [20].

References: [1] Goudge et al. (2015) *JGR 120* 775-808. [2] Goudge et al. (2017) *EPSL 458* 357-365, [3] Ehlmann et al. (2008) *Nat. Geo. 1* 355-358. [4] Ehlmann et al. (2008) *Science 322* 1828-1832. [5] Stack et al. (2020) *SSR 216* 1-47. [6] Horgan et al. (2020) *Icarus 339* 113526. [7] Zastrow & Glotch (2022) *GRL 48* . [8] Siljestrom et al., this vol. [9] Liu et al. (2022) *Science 377* 1513-1519. [10] Wiens et al. (2023) *GSA Connects 55* 264-265. [11] Tarnas et al. (2021) *JGR 126*. [12] Kremer et al. (2019) *Geology 47* 677-681. [13] Ruff et al. (2022) *Icarus 380* 114974. [14] Garczynski et al., this vol. [15] Wiens et al., this vol. [16] Jones et al., this vol. [17] Williams et al., this vol. [18] Hurowitz et al., this vol. [19] Garczynski et al. (2021) *LPSC* #2235. [20] Randazzo et al., this vol.

Figure 2: *Margin unit at Turquoise Bay in enhanced color.*